

## CLAIMS

What is claimed is:

- 1 1. A method for processing data received from a communications channel comprising  
2 the computer-implemented steps of:  
3 receiving, from the communications channel, received data that is based upon both  
4 modulated data and noise, wherein the modulated data is the result of original  
5 data modulated onto one or more carriers;  
6 equalizing the received data to generate equalized data, wherein the equalizing is  
7 performed using an algorithm with a set of one or more coefficients selected  
8 based on noise power and an impulse response of the communications  
9 channel; and  
10 recovering an estimate of the original data by demodulating the equalized data.
- 1 2. The method as recited in Claim 1, wherein the set of one or more coefficients is  
2 selected to optimize an impulse response length of the communications channel to  
3 reduce interference.
- 1 3. The method as recited in Claim 2, wherein the interference includes inter-symbol  
2 interference.
- 1 4. The method as recited in Claim 2, wherein the interference includes inter-channel  
2 interference.
- 1 5. The method as recited in Claim 1, wherein the set of one or more coefficients is  
2 selected to reduce the noise power.
- 1 6. The method as recited in Claim 5, wherein the set of one or more coefficients is  
2 selected to minimize noise power.
- 1 7. The method as recited in Claim 1, wherein the set of one or more coefficients is  
2 selected to simultaneously optimize an impulse response length of the  
3 communications channel to reduce interference and reduce the noise power.

- 1 8. The method as recited in Claim 1, wherein a cyclic prefix is added to the modulated  
2 data and the set of one or more coefficients is selected to ensure that an impulse  
3 response of the communications channel and a device that performs the step of  
4 equalizing is less than a length of the cyclic prefix.
- 1 9. The method as recited in Claim 1, wherein the set of one or more coefficients is  
2 selected to reduce the noise power due to inter-symbol interference, inter-channel  
3 interference, and noise from one or more additional interference sources.
- 1 10. The method as recited in Claim 9, wherein the one or more additional interference  
2 sources includes at least one interference source selected from the group consisting of  
3 crosstalk, amplitude-modulated signals, and white Gaussian noise.
- 1 11. The method as recited in Claim 1, wherein the set of one or more coefficients are  
2 selected by minimizing a function of communications channel impulse response and  
3 noise power.
- 1 12. The method as recited in Claim 1, wherein the set of one or more coefficients are  
2 selected based on a noise power spectral density.
- 1 13. The method as recited in Claim 1, wherein the step of equalizing the received data  
2 includes processing the received data using a finite impulse response (FIR) filter.
- 1 14. The method as recited in Claim 13, wherein the received data is modulated using  
2 discrete multitone modulation and a set of one or more (FIR) coefficients for the FIR  
3 filter is selected to minimize noise power and optimize impulse response length of the  
4 communications channel to reduce interference.
- 1 15. The method as recited in Claim 1, wherein the communications channel is a twisted  
2 pair telephone line.
- 1 16. The method as recited in Claim 1, wherein the twisted pair telephone line uses a  
2 transmission protocol selected from the group consisting of Asymmetric Digital  
3 Subscriber Line (ADSL), G.Lite and Very High Bit Rate DSL (VDSL).

- 1 17. A method for determining coefficients for use in a filter to process data received from  
2 a communications channel comprising the computer-implemented steps of:  
3 determining a communications channel transfer function based on the received data;  
4 determining a noise power spectral density based on the received data;  
5 determining a communications channel impulse response based on the  
6 communications channel transfer function;  
7 determining a noise covariance based on the noise power spectral density; and  
8 determining the coefficients based on the communications channel impulse response  
9 and the noise covariance.
- 1 18. The method as recited in Claim 17, wherein the step of determining the  
2 communications channel transfer function includes the computer-implemented steps  
3 of:  
4 accumulating a plurality of symbol values based on the received data;  
5 determining an average received symbol value based on the received data; and  
6 determining the communications channel transfer function based on the plurality of  
7 symbol values and the average received symbol value.
- 1 19. The method as recited in Claim 17, wherein the step of determining the noise power  
2 spectral density includes the computer-implemented steps of:  
3 measuring a plurality of symbol values based on the received data;  
4 determining an average received symbol value based on the received data; and  
5 determining the noise power spectral density based on the plurality of symbol values  
6 and the average received symbol value.
- 1 20. The method as recited in Claim 17, wherein the step of determining the  
2 communications channel impulse response includes the computer-implemented step  
3 of:  
4 determining the communications channel impulse response based on an inverse fast  
5 Fourier transform (FFT) of the communications channel transfer function.

- 1 21. The method as recited in Claim 17, wherein the step of determining the noise  
2 covariance includes the computer-implemented step of:  
3 determining the noise covariance based on an inverse fast Fourier transform (FFT) of  
4 the noise power spectral density.
- 1 22. The method as recited in Claim 17, wherein the step of determining the coefficients  
2 includes the computer-implemented steps of:  
3 forming two matrices based on the communications channel impulse response and the  
4 noise covariance;  
5 generating a quadratic expression based on the two matrices; and  
6 minimizing the quadratic expression to determine the coefficients.
- 1 23. A computer-readable medium carrying one or more sequences of instructions for  
2 processing data received from a communications channel, wherein execution of the  
3 one or more sequences of instructions by one or more processors causes the one or  
4 more processors to perform the steps of:  
5 receiving, from the communications channel, received data that is based upon both  
6 modulated data and noise, wherein the modulated data is the result of original  
7 data modulated onto one or more carriers;  
8 equalizing the received data to generate equalized data, wherein the equalizing is  
9 performed using an algorithm with a set of one or more coefficients selected  
10 based on noise power and an impulse response of the communications  
11 channel; and  
12 recovering an estimate of the original data by demodulating the equalized data.
- 1 24. The computer-readable medium as recited in Claim 23, wherein the set of one or  
2 more coefficients is selected to optimize an impulse response length of the  
3 communications channel to reduce interference.
- 1 25. The computer-readable medium as recited in Claim 24, wherein the interference  
2 includes inter-symbol interference.

- 1 26. The computer-readable medium as recited in Claim 24, wherein the interference  
2 includes inter-channel interference.
- 1 27. The computer-readable medium as recited in Claim 23, wherein the set of one or  
2 more coefficients is selected to reduce the noise power.
- 1 28. The computer-readable medium as recited in Claim 27, wherein the set of one or  
2 more coefficients is selected to minimize noise power.
- 1 29. The computer-readable medium as recited in Claim 23, wherein the set of one or  
2 more coefficients is selected to simultaneously optimize an impulse response length  
3 of the communications channel to reduce interference and reduce the noise power.
- 1 30. The computer-readable medium as recited in Claim 23, wherein a cyclic prefix is  
2 added to the modulated data and the set of one or more coefficients is selected to  
3 ensure that an impulse response of the communications channel and a device that  
4 performs the step of equalizing is less than a length of the cyclic prefix.
- 1 31. The computer-readable medium as recited in Claim 23, wherein the set of one or  
2 more coefficients is selected to reduce the noise power due to inter-symbol  
3 interference, inter-channel interference, and noise from one or more additional  
4 interference sources.
- 1 32. The computer-readable medium as recited in Claim 31, wherein the one or more  
2 additional interference sources includes at least one interference source selected from  
3 the group consisting of crosstalk, amplitude-modulated signals, and white Gaussian  
4 noise.
- 1 33. The computer-readable medium as recited in Claim 23, wherein the set of one or  
2 more coefficients are selected by minimizing a function of communications channel  
3 impulse response and noise power.
- 1 34. The computer-readable medium as recited in Claim 23, wherein the set of one or  
2 more coefficients are selected based on a noise power spectral density.

1 35. The computer-readable medium as recited in Claim 23, wherein the instructions for  
2 equalizing the received data further comprise instructions which, when executed by  
3 the one or more processors, cause the one or more processors to carry out the step of  
4 processing the received data using a finite impulse response (FIR) filter.

1 36. The computer-readable medium as recited in Claim 35, wherein the received data is  
2 modulated using discrete multitone modulation and a set of one or more (FIR)  
3 coefficients for the FIR filter is selected to minimize noise power and optimize  
4 impulse response length of the communications channel to reduce interference.

1 37. The computer-readable medium as recited in Claim 23, wherein the communications  
2 channel is a twisted pair telephone line.

1 38. The computer-readable medium as recited in Claim 23, wherein the twisted pair  
2 telephone line uses a transmission protocol selected from the group consisting of  
3 Asymmetric Digital Subscriber Line (ADSL), G.Lite and Very High Bit Rate DSL  
4 (VDSL).

1 39. A computer-readable medium carrying one or more sequences of instructions for  
2 determining coefficients for use in a filter to process data received from a  
3 communications channel, wherein execution of the one or more sequences of  
4 instructions by one or more processors causes the one or more processors to perform  
5 the steps of:  
6 determining a communications channel transfer function based on the received data;  
7 determining a noise power spectral density based on the received data;  
8 determining a communications channel impulse response based on the  
9 communications channel transfer function;  
10 determining a noise covariance based on the noise power spectral density; and  
11 determining the coefficients based on the communications channel impulse response  
12 and the noise covariance.

1 40. The computer-readable medium as recited in Claim 39, wherein the instructions for  
2 determining the communications channel transfer function further comprise  
3 instructions which, when executed by the one or more processors, cause the one or  
4 more processors to carry out the steps of:  
5 accumulating a plurality of symbol values based on the received data;  
6 determining an average received symbol value based on the received data; and  
7 determining the communications channel transfer function based on the plurality of  
8 symbol values and the average received symbol value.

1 41. The computer-readable medium as recited in Claim 39, wherein the instructions for  
2 determining the noise power spectral density further comprise instructions which,  
3 when executed by the one or more processors, cause the one or more processors to  
4 carry out the steps of:  
5 measuring a plurality of symbol values based on the received data;  
6 determining an average received symbol value based on the received data; and  
7 determining the noise power spectral density based on the plurality of symbol values  
8 and the average received symbol value.

1 42. The computer-readable medium as recited in Claim 39, wherein the instructions for  
2 determining the communications channel impulse response further comprise  
3 instructions which, when executed by the one or more processors, cause the one or  
4 more processors to carry out the step of:  
5 determining the communications channel impulse response based on an inverse fast  
6 Fourier transform (FFT) of the communications channel transfer function.

1 43. The computer-readable medium as recited in Claim 39, wherein the instructions for  
2 determining the noise covariance further comprise instructions which, when executed  
3 by the one or more processors, cause the one or more processors to carry out the step  
4 of:  
5 determining the noise covariance based on an inverse fast Fourier transform (FFT) of  
6 the noise power spectral density.

1 44. The computer-readable medium as recited in Claim 39, wherein the instructions for  
2 determining the coefficients further comprise instructions which, when executed by  
3 the one or more processors, cause the one or more processors to carry out the steps of:  
4 forming two matrices based on the communications channel impulse response and the  
5 noise covariance;  
6 generating a quadratic expression based on the two matrices; and  
7 minimizing the quadratic expression to determine the coefficients.

1 45. An apparatus for processing data received from a communications channel  
2 comprising:  
3 an equalizer configured to equalize received data from the communications channel  
4 and generate equalized data, wherein the received data is based upon both  
5 modulated data and noise, and the modulated data is the result of original data  
6 modulated onto one or more carriers, and wherein the equalizer is configured  
7 to use an algorithm with a set of one or more coefficients selected based on  
8 noise power and an impulse response of the communications channel; and  
9 a demodulator configured to generate an estimate of the original data by  
10 demodulating the equalized data.

1 46. The apparatus as recited in Claim 45, wherein the set of one or more coefficients is  
2 selected to optimize an impulse response length of the communications channel to  
3 reduce interference.

1 47. The apparatus as recited in Claim 46, wherein the interference includes inter-symbol  
2 interference.

1 48. The apparatus as recited in Claim 46, wherein the interference includes inter-channel  
2 interference.

1 49. The apparatus as recited in Claim 45, wherein the set of one or more coefficients is  
2 selected to reduce the noise power.



- 1 50. The apparatus as recited in Claim 49, wherein the set of one or more coefficients is  
2 selected to minimize noise power.
- 1 51. The apparatus as recited in Claim 45, wherein the set of one or more coefficients is  
2 selected to simultaneously optimize an impulse response length of the  
3 communications channel to reduce interference and reduce the noise power.
- 1 52. The apparatus as recited in Claim 45, wherein a cyclic prefix is added to the  
2 modulated data and the set of one or more coefficients is selected to ensure that an  
3 impulse response of the communications channel and the equalizer is less than a  
4 length of the cyclic prefix.
- 1 53. The apparatus as recited in Claim 45, wherein the set of one or more coefficients is  
2 selected to reduce the noise power due to inter-symbol interference, inter-channel  
3 interference, and noise from one or more additional interference sources.
- 1 54. The apparatus as recited in Claim 53, wherein the one or more additional interference  
2 sources includes at least one interference source selected from the group consisting of  
3 crosstalk, amplitude-modulated signals, and white Gaussian noise.
- 1 55. The apparatus as recited in Claim 45, wherein the set of one or more coefficients are  
2 selected by minimizing a function of communications channel impulse response and  
3 noise power.
- 1 56. The apparatus as recited in Claim 45, wherein the set of one or more coefficients are  
2 selected based on a noise power spectral density.
- 1 57. The apparatus as recited in Claim 45, wherein the equalizer is configured to process  
2 the received data using a finite impulse response (FIR) filter.
- 1 58. The apparatus as recited in Claim 57, wherein the received data is modulated using  
2 discrete multitone modulation and a set of one or more (FIR) coefficients for the FIR  
3 filter is selected to minimize noise power and optimize impulse response length of the  
4 communications channel to reduce interference.

1 59. The apparatus as recited in Claim 45, wherein the communications channel is a  
2 twisted pair telephone line.

1 60. The apparatus as recited in Claim 45, wherein the twisted pair telephone line uses a  
2 transmission protocol selected from the group consisting of Asymmetric Digital  
3 Subscriber Line (ADSL), G.Lite and Very High Bit Rate DSL (VDSL).

1 61. An apparatus for determining coefficients for use in a filter to process data received  
2 from a communications channel comprising:  
3 means for determining a communications channel transfer function based on the  
4 received data;  
5 means for determining a noise power spectral density based on the received data;  
6 means for determining a communications channel impulse response based on the  
7 communications channel transfer function;  
8 means for determining a noise covariance based on the noise power spectral density;  
9 and  
10 means for determining the coefficients based on the communications channel impulse  
11 response and the noise covariance.

1 62. The apparatus as recited in Claim 61, wherein the means for determining the  
2 communications channel transfer function includes:  
3 means for accumulating a plurality of symbol values based on the received data;  
4 means for determining an average received symbol value based on the received data;  
5 and  
6 means for determining the communications channel transfer function based on the  
7 plurality of symbol values and the average received symbol value.

1 63. The apparatus as recited in Claim 61, wherein the means for determining the noise  
2 power spectral density includes:  
3 means for measuring a plurality of symbol values based on the received data;  
4 means for determining an average received symbol value based on the received data;  
5 and  
6 means for determining the noise power spectral density based on the plurality of  
7 symbol values and the average received symbol value.

1 64. The apparatus as recited in Claim 61, wherein the means for determining the  
2 communications channel impulse response includes:  
3 means for determining the communications channel impulse response based on an  
4 inverse fast Fourier transform (FFT) of the communications channel transfer  
5 function.

1 65. The apparatus as recited in Claim 61, wherein the means for determining the noise  
2 covariance includes:  
3 means for determining the noise covariance based on an inverse fast Fourier  
4 transform (FFT) of the noise power spectral density.

1 66. The apparatus as recited in Claim 61, wherein the means for determining the  
2 coefficients includes:  
3 means for forming two matrices based on the communications channel impulse  
4 response and the noise covariance;  
5 means for generating a quadratic expression based on the two matrices; and  
6 means for minimizing the quadratic expression to determine the coefficients.

1 67. A method for generating coefficient data comprising the computer-implemented step  
2 of generating coefficient data that represents a set of one or more coefficients that are  
3 selected based on noise power and an impulse response of a communications channel  
4 when the coefficients are used with an algorithm to equalize received data from the  
5 communications channel, wherein the received data is based upon both modulated  
6 data and noise and the modulated data is the result of original data modulated onto  
7 one or more carriers.

1 68. A computer-readable medium carrying coefficient data that represents a set of one or  
2 more coefficients that are selected based on noise power and an impulse response of a  
3 communications channel when the coefficients are used with an algorithm to equalize  
4 received data from the communications channel, wherein the received data is based  
5 upon both modulated data and noise and the modulated data is the result of original  
6 data modulated onto one or more carriers.

1 69. An apparatus for generating coefficient data comprising:  
2 a storage medium for storing the coefficient data; and  
3 a coefficient generator configured to generate the coefficient data, wherein the  
4 coefficient data represents a set of one or more coefficients that are selected  
5 based on noise power and an impulse response of a communications channel  
6 when the coefficients are used with an algorithm to equalize received data  
7 from the communications channel, wherein the received data is based upon  
8 both modulated data and noise and the modulated data is the result of original  
9 data modulated onto one or more carriers.